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Polymorphism in Pseudoscorpions. II. Changes of Abdominal Segmentation Pattern in *Neobisium carpaticum* and *Roncus pannonius* (Pseudoscorpiones: Neobisiidae)

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Abstract Polymorphism in abdominal sclerite pattern was studied in *Neobisium carpaticum* BEIER, 1935, *and Roncus pannonius* ĆURČIĆ, DIMITRIJEVIĆ et KARAMATA, 1992 (Neobisiidae, Pseudoscorpiones), both inhabiting Yugoslavia. A total of 58 examples of *N. carpaticum* and 57 specimens of *R. pannonius*, with changes of this pattern (1.53% and 0.87%, respectively) were found out of 3,794 and 6,570 specimens examined, respectively. Variation of sclerite pattern was confined mostly to adults and less to the subadult stages. In *N. carpaticum*, as many as 11 different single or combined changes in the sclerite pattern were noted; in *R. pannonius*, there were 14 types of such deviations. The most frequent variants in the two species were: partial atrophy, symphysomery, combined partial atrophy and symphysomery, and combined hemimery and sclerite enlargement; all other changes in the sclerite pattern were less frequent. Statistical analysis showed that only males of *N. carpaticum* and females of *R. pannonius* exhibit significant and marginally significant asymmetry in the changes of the sclerite pattern, respectively. Additionally, the adults (both females and males) of *N. carpaticum* exhibited marginal significance, while the adults of *R. pannonius* showed significant differences between the occurrence of changed abdominal segmentation on the left and right. The probable causes for this phenomenon were also discussed. Apart from some physical, mechanical, and chemical factors, it is assumed that both developmental and genetic factors cause the changes in the abdominal sclerite pattern.

Introduction

Each pseudoscorpion possesses a specific pattern of abdominal sclerites (tergites and sternites). Species-specific distribution of tergites and sternites produces a set of "normal" phenotypes. The absence, duplication, reduction in part of a sclerite, or disturbed setation give rise to changes in the normal sclerite pattern. If individuals with such deviations attained elevated frequencies within natural populations (for instance, if more than 1% of examples exhibited such phenotypes), this could be one manifestation of species polymorphism. Elevated frequencies of deviations from the normal pattern of abdominal sclerites could be then ascribed to certain environmental events, or to significant changes in the population structure of the species (ĆURČIĆ *et al.*, 1991, 1995; LUČIĆ, 1995) such as population bottleneck where inbreeding depression and genetic drift could be major factors in their promoting.

False scorpions have been found with deviations of abdominal sclerites involving atrophy, loss, duplication, omission of a part of (or of a whole) sclerite, spiral alignment

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of tergites and/or sternites, as well as their partial or complete fusion. Records of the changes in the sclerite patterns in pseudoscorpions are numerous and include both brief reports on different aberrations of abdominal tergites and sternites (With, 1905; Kästner, 1927; Gilbert, 1952; Hadži, 1930; Ćurčić and Dimitrijević, 1983, 1984a, 1984b, 1987, 1990a, 1991) and studies which attempted both to qualify and quantify the phenomenon (Pedder, 1965; Ćurčić, 1980, 1989a, 1989b; Ćurčić & Dimitrijević, 1982, 1985, 1986a, 1986b, 1988a, 1988b, 1990a, 1990b; Ćurčić *et al.*, 1981, 1983, 1995; Dimitrijević, 1990b; Ivanović, 1987; Zlatković, 1989; Lučić, 1995).

Abdominal malformations in representatives of the Chthonioidea have been noted in: *Allochthonius opticus* (Ellingsen, 1907) (Chthoniidae), from Japan, with hemiatrophy of tergite III; and with combined symphysomery, hemiatrophy, and partial atrophy of tergites II–VII (Sato, 1992); *Chthonius (Chthonius) ischnocheles* (Hermann, 1804), from Yugoslavia and France, respectively (Ćurčić & Dimitrijević, 1987, 1990b; Dimitrijević, 1990a); *Chthonius (C.) tenuis* L. Koch, 1873, from the United Kingdom (Pedder, 1965); and *Chthonius (Ephippiochthonius)* aff. *tetrachelatus* (Preyssler, 1790) (from Yugoslavia and France, respectively) (Ćurčić & Dimitrijević, 1990b; Dimitrijević, 1990a, 1992). As far as *C. (C.) ischnocheles* is concerned, the percentage of specimens with anomalous sclerites varied from 0–10.28%, depending on the site; the majority of such deviations were confined to males (77%), less to females (17%) and the least to tritonymphs (6%). Symphysomery (single and multiple) accounts for more than 90% of the total number of anomalies in this species, other (single and combined) anomalies being less frequent (Ćurčić *et al.*, 1995; Ćurčić & Dimitrijević, 1990b; Dimitrijević, 1990a). Combinations of two and more anomalies are far less abundant than single aberrations (Ćurčić *et al.*, 1995).

In *C. (C.) tenuis*, a single aberrant male was described (Pedder, 1965), exhibiting both hemiatrophy of tergite IV and partial atrophy of tergite V; the percentage of anomalous specimens in this sample was 0.2%. Additionally, in the majority of samples of *C. (E.)* aff. *tetrachelatus* from Yugoslavia and France, neither Ćurčić and Dimitrijević (1990b) nor Dimitrijević (1990a) found no aberrations of abdominal sclerites. However, a single sample from Yugoslavia yielded one anomalous male of the species (with both symphysomery and tergite enlargement; Dimitrijević, 1992), which resulted in an overall rate of aberrant specimens of 0.09% (Ćurčić *et al.*, 1995; Dimitrijević, 1992).

Among the Garypoidea, a male of *Garypus japonicus* Beier, 1952 (Garypidae), from Japan, was noted for a combination of tergite atrophy, (?) hemimery, and symphysomery (Sato, 1992); and a male of *Synsphyronus mimetus* Chamberlin, 1943, from Australia, was found with combined monocyclic sinistral helicomery and multiple tergal enlargement (Chamberlin, 1949). Additionally, an adult (of unknown sex) of *Horus granulatus* (Ellingsen, 1912) (Olpiidae), from South Africa, was found to exhibit a combination of partial symphysomery and partial atrophy of tergites (Beier, 1955). Furthermore, a paratype male of *Minniza monticola* Mahnert, 1991, from Saudi Arabia, was found with combined partial atrophy and symphysomery of tergites I and II (Ćurčić *et al.*, 1995; Mahnert, 1991).

In the Neobisioidea, sclerite deficiencies were recorded in 16 species and 2 genera of the family Neobisiidae; these are: *Neobisium bernardi* Vachon, 1937, *N. carcinoides* (Hermann, 1804), *N. carpaticum* Beier, 1935, *N. cephalonicum* (Daday, 1888), *N. erythrodactylum* (L. Koch, 1873), *N.* aff. *fuscimanum* (C. L. Koch, 1873), *N. ma-*

crodactylum (DADAY, 1888), *N. maritimum* (LEACH, 1817), *N. svetovidi* ĆURČIĆ, 1988, *N. simoni* (L. KOCH, 1873), *N. stygium* BEIER, 1931, *N. sylvaticum* (C. L. KOCH, 1835), *Roncus jarilo* ĆURČIĆ, 1992, *R. pannonius* ĆURČIĆ, DIMITRIJEVIĆ, et KARAMATA, 1992, *R.* aff. *stussineri* (SIMON, 1881), and *R. tintilin* ĆURČIĆ, 1993 (ĆURČIĆ *et al.*, 1995). The overall rate of changes in sclerite structures varied from 0-6.45% in *Neobisium* representatives, and from 0.46-1.07% in *Roncus* representatives, depending both on the species and site (ĆURČIĆ *et al.*, 1995). In *N. carpaticum*, otherwise studied in great detail, the following sclerite deviations were observed: partial atrophy (single and multiple), symphysomery (single and multiple), as well as combinations of different anomalies. Both atrophy and symphysomery account for more than 60% of all anomalies noted, while combined anomalies are much less frequent (ĆURČIĆ & DIMITRIJEVIĆ, 1988a, 1988b; ĆURČIĆ *et al.*, 1995; LUČIĆ, 1995). Like in *Chthonius*, sternite aberrations are far less frequent than those affecting tergites.

Further analyses have clearly shown that each sclerite anomaly (or a group of such deviations) exhibits a distinct polarity along the antero-posterior abdominal axis, both in *Neobisium* and *Roncus* studied (ĆURČIĆ & DIMITRIJEVIĆ, 1988a; ĆURČIĆ *et al.*, 1995; LUČIĆ, 1995). However, the frequency and distribution of these anomalies are probably genus-, or perhaps even species-specific. It has been also noted that the degree of changes in sclerite setation is often correlated to the area affected by different abdominal anomalies.

Among the Cheliferoidea, several members of Atemnidae, Cheliferidae, and Chernetidae were found with different sclerite anomalies. Thus, a male of *Anatemnus javanus* (THORELL, 1883) (Atemnidae), from Burma, developed a monocyclic sinistral helicomery (WITH, 1905). Additionally, GILBERT (1952) and PEDDER (1965) found in *Dactylochelifer latreillei* (LEACH, 1817) (Cheliferidae), from the United Kingdom an incidence of 0.84-2.50% of anomalous specimens (ĆURČIĆ *et al.*, 1995); the following deviations were noted: a female with monocyclic dextral helicomery and tergal enlargement; a female with tergal hemimery; a male with multiple tergal symphysomery; as well as 2 males and 2 deutonymphs with mono-, bi-, and tricyclic helicomery, respectively (PEDDER, 1965). DASHDAMIROV and SCHAWALLER (1995) recorded a female of *Dactylochelifer intermedius* (REDIKORZEV, 1949) (Cheliferidae), from Tadjikistan, with a partial multiple symphysomery of tergites VIII-X.

In addition, a number of sclerite abnormalites were noted in *Ellingsenius fulleri* (HEWITT et GODFREY, 1929) (Cheliferidae), from Mozambique: a male with partial helicomery and symphysomery; and a female with combined multiple atrophy and tergite enlargement (JUDSON, 1990). Further anomaly was developed in a female of *Ellingsenius sculpturatus* (LEWIS, 1903) (locality unknown), with combined partial symphysomery, tergite enlargement and monocyclic helicomery (WITH, 1905). A similar deviation was noted in *Rhacochelifer corcyrensis* (BEIER, 1930), from Croatia (HADŽI, 1930).

Qualitative and quantitative analyses of abdominal malformations in *Lamprochernes nodosus* (SCHRANK, 1903) (Chernetidae), from the United Kingdom have shown that the overall rate of anomalous examples varied from 0.84-2.50% (ĆURČIĆ *et al.*, 1995); only combined partial atrophy (single and multiple) and tergite enlargement was noted in this species. Furthermore, a combination of partial tergite atrophy, hemimery, and tergite enlargement was noted in an individual of *Allochernes wideri* (C. L. KOCH, 1843) (locality unknown) (Chernetidae); additionally, a female of *Chernes cimicoides*

(FABRICIUS, 1793), from Germany, was characterised by the presence of tergal atrophy and incomplete symphysomery (WEYGOLDT, 1969; DROGLA, 1988). An abdominal aberration including both tergites and sternites, was recorded in a male of *Myrmochernes africanus* (TULLGREN, 1907) (Chernetidae), from South Africa (JUDSON, 1985). Finally, in *Pselaphochernes dubius* (O. P.-CAMBRIDGE, 1892) (Chernetidae), from the United Kingdom, a single female was found to exhibit either partial atrophy and tergal enlargement, or incomplete monocyclic helicomery (PEDDER, 1965; ĆURČIĆ *et al.*, 1995).

The primary aim of this study was both to analyse the qualitative and quantitative variation of abdominal sclerite patterns in one south-east European species of *Neobisium* and in one endemic species of the Balcanic *Roncus* (both from Yugoslavia), and the probable factors affecting the origin, development and distribution of such deviations.

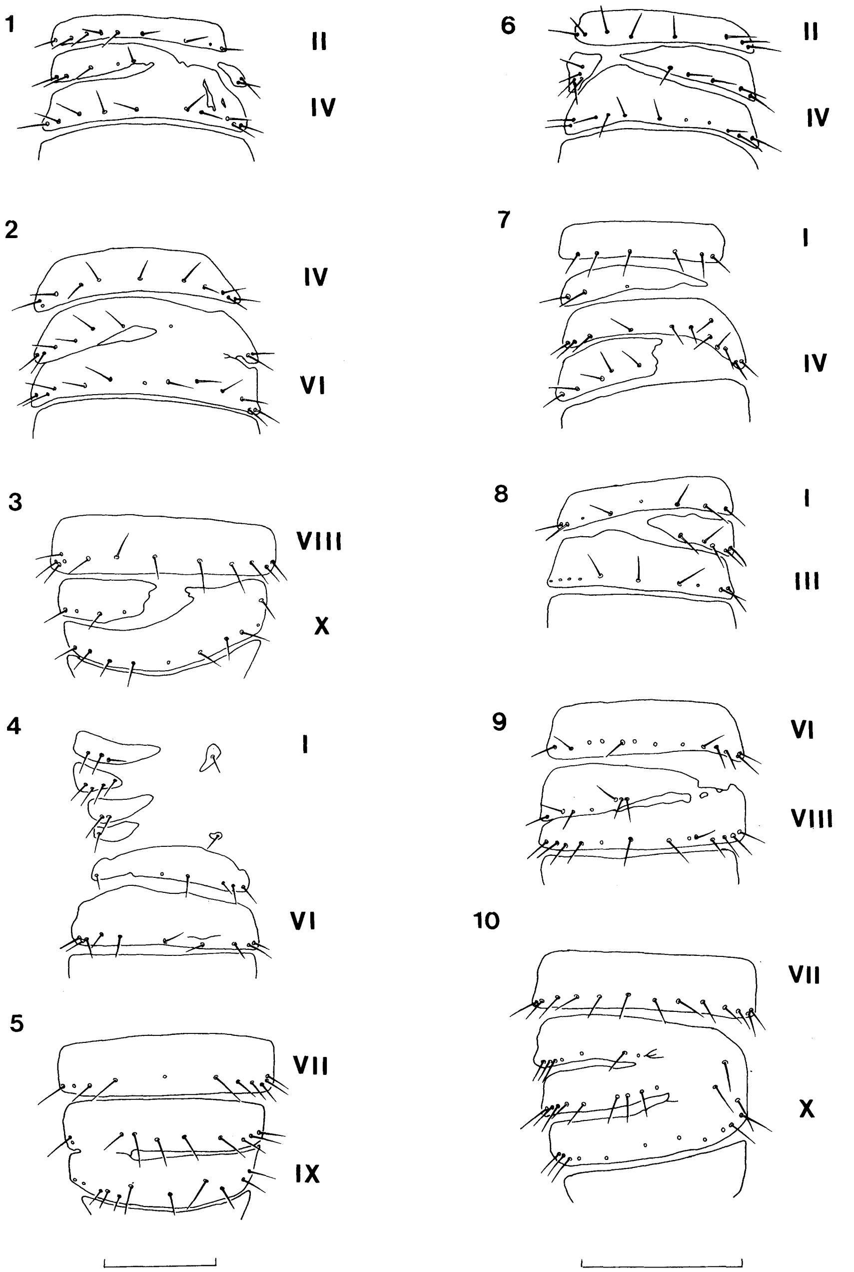
Material and Methods

We have analysed the variants of the abdominal sclerite (tergite and sternite) patterns in a population of *Neobisium carpaticum* BEIER, 1935, from the village of Obrež, near Belgrade, Yugoslavia. A total of 3,794 specimens were examined, comprising 1,121 females, 1,529 males, 693 tritonymphs, 233 deutonymphs, and 218 protonymphs. Samples of this species were obtained by sifting oak and beech litter and humus over a period from April 1993 to November 1993; samples were taken at least once a month. Additionally, 6,570 specimens of *Roncus pannonius* ĆURČIĆ, DIMITRIJEVIĆ et KARAMATA, 1992, were examined for the same purpose; this lot included 2,041 females, 2,935 males, 1,516 tritonymphs, 77 deutonymphs and 1 protonymph, collected from April 1989 to September 1990, and from April 1993 to November 1993 at the same site.

After dissection, all anomalous specimens were mounted in Swan's fluid (gum chloral medium) and examined carefully. The terminology for sclerite aberrations in this study follows that given by ĆURČIĆ *et al.* (1995). However, this terminology has been somewhat modified in the present paper to include the whole range of polymorphism in sclerite structure of both *N. carpaticum* and *R. pannonius* studied. The trichobothrial designations follow BEIER (1932).

Results and Discussion

There were a total of 58 specimens of *N. carpaticum* (23 ♀♀, 29 ♂♂, 3 tritonymphs, and 3 deutonymphs) and 57 specimens of *R. pannonius* (22 ♀♀, 30 ♂♂, 4 tritonymphs, and 1 deutonymph) with changed patterns of abdominal segmentation, representing 1.53% and 0.87% of all examined individuals of each species, respectively (Figs. 1–10). In both species, this percentage is higher than the corresponding values which refer to the frequency of either cheliceral or pedal anomalies (ĆURČIĆ *et al.*, 1994, 1995); however, anomalies of abdominal sclerites are less frequent than trichobothrial aberrations in *R. pannonius* (ĆURČIĆ *et al.*, 1996) (aberrations of trichobothriotaxy have not been studied in *N. carpaticum*). The analysis of the sample of *N. carpaticum* showed that phenotypical variation of sclerite pattern was confined mostly to females (39.65%) and males (50.00%), and less to tritonymphs and deutonymphs (5.17% each) (Table 1). The corresponding values for *R. pannonius* are: 38.60% (females), 52.63%



Figs. 1–10. Anomalies of abdominal sclerites in *Neobisium carpaticum* BEIER (1–5) and *Roncus pannonius* ĆURČIĆ, DIMITRIJEVIĆ et KARAMATA (6–10), from Yugoslavia: 1, tergites II–IV, female; 2, tergites IV–VI, female; 3, tergites VIII–X, female; 4, tergites I–VI, male; 5, tergites VII–IX, male; 6, tergites II–IV, female; 7, tergites I–IV, male; 8, tergites I–III, male; 9, sternites, VI–VIII, male; 10, sternites VII–X, male. Scale lines = 0.5 mm.

Table 1. Frequency of different variants of abdominal segmentation in *Neobisium carpaticum* BEIER, 1935 (expressed as a percentage of the total number, n=58, of these changes). Abbreviations: T=tritonymphs, D=deutonymphs, %S=percentage of the relevant changes on the left, %D=percentage of the relevant changes on the right.

	♀♀	♂♂	T	D	Total	%S	%D
Partial atrophy							
- single	6.91	17.25	3.45	1.73	29.34	23.53	76.47
- multiple	8.62	3.45	—	—	12.07	57.14	42.86
Symphysomery							
- single	10.35	12.07	—	1.72	24.14	42.86	57.14
Combined partial atrophy and tergite enlargement	3.45	6.90	—	1.72	12.07	85.71	14.29
Combined partial atrophy and symphysomery	5.17	5.17	1.72	—	12.06	0	100.00
Combined partial atrophy and the occurrence of a supernumerary tergite	1.72	—	—	—	1.72	0	100.00
Combined partial atrophy and multiple tergite enlargement	—	1.72	—	—	1.72	0	100.00
Combined multiple partial atrophy and tergite enlargement	1.72	—	—	—	1.72	0	100.00
Combined multiple partial atrophy, multiple hemimery, and tergite enlargement	—	1.72	—	—	1.72	0	100.00
Combined hemimery and tergite enlargement	1.72	—	—	—	1.72	0	100.00
Combined symphysomery and partial helicomery	—	1.72	—	—	1.72	100.00	0
Total	39.65	50.00	5.17	5.17	100.00		
Mean						28.11	71.89

(males), 7.02% (tritonymphs), and 1.75% (deutonymphs) (Table 2).

The deficiencies in the abdominal sclerites (tergites and sternites) were variable. Thus, in the species analysed, as many as 11 (*N. carpaticum*) and 14 (*R. pannonius*) different, single or combined, changes in the sclerite pattern were noted (Tables 1 and 2; Figs. 1–10). Among these, the changes affecting tergites are much more frequent than those affecting sternites (94.83% *vs*. 5.17% in *N. carpaticum* and 80.70% *vs*. 19.30% in *R. pannonius*) (see also ĆURČIĆ *et al*., 1995, 1996).

The study of the frequency and relative distribution of abdominal sclerite changes in *N. carpaticum* and *R. pannonius* revealed the following: 1) variations in sclerite pattern are manifested by the simultaneous changes in the structure and setation of the corresponding tergites and/or sternites; 2) the most frequent variants of abdominal deficiencies were: partial atrophy (single or multiple) (41.41% in *N. carpaticum*, 19.33% in *R. pannonius*), symphysomery (single or multiple) (24.14% in *N. carpaticum*, 22.80% in *R. pannonius*), combined partial atrophy and symphysomery (12.06% in *N. carpaticum*, 10.53% in *R. pannonius*), and combined hemimery and sclerite enlargement (none in *N. carpaticum*, 12.28% in *R. pannonius*); all other changes of abdominal sclerites were less frequent, both in *N. carpaticum* (1.72% each) and *R. pannonius* (1.75–7.02% each) (Tables 1 and 2); 3) the relative positions of each sclerite variant along the

Table 2. Frequency of different variants of abdominal segmentation in *Roncus pannonius* ĆURČIĆ, DIMITRIJEVIĆ, et KARAMATA, 1992 (expressed as a percentage of total number, n=57, of these changes). Abbreviations: as in Table 1.

	♀♀	♂♂	T	D	Total	%S	%D
Hemimery	3.51	—	—	—	3.51	100.00	0
Partial atrophy							
- single	7.02	8.80	—	—	15.82	77.78	22.22
- multiple	—	3.51	—	—	3.51	50.00	50.00
Symphysomery							
- single	3.51	12.28	1.76	1.75	19.30	72.73	27.27
- multiple	—	1.75	1.75	—	3.50	50.00	50.00
Combined hemimery and sclerite enlargement	7.02	5.26	—	—	12.28	57.14	42.86
Combined partial atrophy and tergite enlargement	7.02	1.75	1.75	—	10.52	33.33	66.67
Combined partial atrophy and sternite enlargement	—	1.75	—	—	1.75	100.00	0
Combined partial atrophy, hemimery, and tergite enlargement	—	1.75	—	—	1.75	0	100.00
Combined partial atrophy and symphysomery	3.51	5.26	1.76	—	10.53	66.67	33.33
Combined partial atrophy and symphysomery (or helicomery)	1.75	3.51	—	—	5.26	33.33	66.67
Combined partial atrophy, symphysomery and tergite enlargement	3.51	3.51	—	—	7.02	25.00	75.00
Combined partial atrophy, helicomery and tergite enlargement	1.75	1.75	—	—	3.50	100.00	0
Combined helicomery, multiple symphysomery, and tergite enlargement	—	1.75	—	—	1.75	100.00	0
Total	38.60	52.63	7.02	1.75	100.00		
Mean						61.86	38.14

antero-posterior axis follow general conclusions for *N. carpaticum* and *R. pannonius* presented elsewhere (ĆURČIĆ *et al.*, 1995; LUČIĆ, 1995).

The sclerite changes studied in *N. carpaticum* are predominantly dextral (71.89%), while in *R. pannonius*, these are predominantly sinistral (61.86%). Additionally, the frequency of different sclerite changes, expressed as a percentage of the numbers of specimens examined for each stage and species (values for *R. pannonius* are in parentheses) revealed that 2.05% (1.08%) of females showed such changes, 1.90% (1.02%) of males, 0.43% (0.26%) of tritonymphs and 1.29% (1.30%) of deutonymphs, respectively.

Both dextral and sinistral occurrence of trichobothrial changes ("asymmetry") was tested statistically (chi-square test) for all adult specimens of the two species studied (other, preadult stages were not analysed due to their small sample size). The results of this analysis in *N. carpaticum* revealed marginally significant (chi-square=3.77; $0.05 < P < 0.1$) (more changes on the right) and in *R. pannonius* significant differences between the occurrence of changed abdominal segmentation on the left and right (chi-square=

4.92; $P<0.05$) (more changes on the left). However, when males and females of each species were tested separately for asymmetry, a subsequent analysis clearly showed the sex differences in relation to the distribution of changed sclerite variants. It seems that only males of *N. carpaticum* (chi-square=5.83; $P<0.02$) exhibit significant presence of asymmetry in the sclerite pattern (more changes on the right), but not females (chi-square=0.04; $P>0.05$). In *R. pannonius*, however, only females (chi-square=2.91; $0.05<P<0.1$) exhibit marginally significant presence of asymmetry in both tergite and sternite pattern (more changes on the left), but not males (chi-square=2.13; $P>0.05$).

Until additional information (including much larger samples) become available, it is difficult to present a plausible interpretation of the sexual differences in the distribution of changed sclerite patterns in the two species studied. However, one of the possible explanations of the sexual dimorphism (in relation to asymmetry in sclerite variants) could be the presence of a more intensive selection (? sexual) against asymmetry in females of *N. carpaticum* and in males of *R. pannonius*, and of a less intensive selection in males of *N. carpaticum* and in females of *R. pannonius*. This view is supported by the fact that both the abdomen (opisthosoma) and its sclerites play an important role, not only in protecting internal systems and organs and bearing the genital and respiratory openings, but also in reproduction and development and in making "social contact" in courtship and mating (WEYGOLDT, 1969).

Apart from some physical, mechanical, and chemical factors (ĆURČIĆ, 1980; ĆURČIĆ *et al.*, 1995), it is probable that both developmental and genetic factors spark the origin of changes in the sclerite pattern in both *N. carpaticum* and *R. pannonius*. Some of these factors influence the origin of such changes immediately after gastrulation, when the rudiment of the opisthosoma is formed; this structure possesses a distinct proliferation zone that forms the segments, beginning at the anterior end and progressing posteriorly (WEYGOLDT, 1969). Other deviation-provoking factors are probably active during postembryogenesis or during each of the moulting periods (ĆURČIĆ *et al.*, 1995).

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References

BEIER, M., 1932. Pseudoscorpionidea I. Subord. Chthoniinea et Neobisiinea. *Tierreich*, **57**: 1–258.

—— 1955. Pseudoscorpionida. In: *S. Afr. Anim. Life*, **1**, pp. 263–328.

CHAMBERLIN, J. C., 1949. New and little-known false scorpions from various parts of the world (Arachnida, Chelonethi), with notes on structural abnormalities in two species. *Amer. Mus. Novit.*, (1430): 1–57.

ĆURČIĆ, B. P. M., 1980. Accidental and teratological changes in the family Neobisiidae (Pseudoscorpiones, Arachnida). *Bull. Br. arachnol. Soc.*, **5**: 9–15.

—— 1989a. Segmental anomalies in some European Neobisiidae (Pseudoscorpiones, Arachnida). Part I. *Acta arachnol.*, **37**: 77–87.

—— 1989b. Segmental anomalies in some European Neobisiidae (Pseudoscorpiones, Arachnida). Part

II. *Ibid*., **38**: 1-10.

ČURČIĆ, B. P. M., & R. N. DIMITRIJEVIĆ, 1982. On abnormalites of abdominal segmentation in *Neobisium carpaticum* BEIER (Neobisiidae, Pseudoscorpiones, Arachnida). *Rev. arachnol*., **4**: 143-150.

—— & —— 1983. Three more examples of abnormal segmentation of the abdomen in *Neobisium carpaticum* BEIER, 1934 (Arachnida: Pseudoscorpiones: Neobisiidae). *Proc. entomol. Soc. Wash*., **85**: 362-365.

—— & —— 1984a. Two more examples of sternal anomaly in *Neobisium carpaticum* BEIER and *Roncus lubricus* L. KOCH (Pseudoscorpiones, Arachnida). *Proc. X SIEEC, Budapest (1983)*, **1**: 283-285.

—— & —— 1984b. An abnormal carapaco-abdominal junction in *Neobisium carpaticum* BEIER, 1934 (Neobisiidae, Pseudoscorpiones). *Arch. Biol. Sci., Belgrade*, **36**: 9P-10P.

—— & —— 1985. Abdominal deficiencies in four species of the Neobisiidae (Pseudoscorpiones, Arachnida). *Rev. arachnol*., **6**: 91-98.

—— & —— 1986a. Teratology of abdominal tergites and sternites in *Neobisium carpaticum* BEIER (Neobisiidae, Pseudoscorpiones). *Mém. Soc. r. belge Entom*., **33**: 81-84.

—— & —— 1986b. Abnormalities of carapacal and abdominal segmentation in *Neobisium* CHAMBERLIN (Neobisiidae, Pseudoscorpiones). *Actas X Congr. Int. Aracnol., Jaca-España*, **1**: 17-23.

—— & —— 1987. Two segmental anomalies in *Chthonius ischnocheles* (HERMANN) (Chthoniidae, Pseudoscorpiones). *Arch. Biol. Sci., Belgrade*, **39**: 1P-2P.

—— & —— 1988a. Segmental anomalies in *Neobisium carpaticum* BEIER (Neobisiidae, Pseudoscorpiones) from the Botanical Garden in Belgrade, Yugoslavia. *Fragmenta balcanica*, **13**: 135-150.

—— & —— 1988b. Segmental deficiencies in some Neobisiidae (Pseudoscorpiones, Arachnida). *C. R. XI. Europ. Coll. Arachnol., Berlin (1988), TUB-Dokumentation*, **38**: 89-97.

—— & —— 1990a. An example of partial duplication of the abdomen in *Neobisium simoni* (L. KOCH) (Pseudoscorpiones, Neobisiidae). *J. Arachnol*., **18**: 113-115.

—— & —— 1990b. Teratological variation in *Chthonius ischnocheles* (HERMANN) and *C.* aff. *tetrachelatus* (PREYSSLER) (Chthoniidae, Pseudoscorpiones). *C. R. XII Coll. europ. Arachnol., Paris* (1990), **1**: 90-96.

—— & —— 1991. An example of carapaco-abdominal fusion in *Neobisium* aff. *fuscimanum* (Arachnida, Pseudoscorpiones, Neobisiidae). *J. Arachnol*., **19**: 225-226.

——, ——, O. S. KARAMATA, & L. R. LUČIĆ., 1991. Segmental anomalies in *Roncus* aff. *lubricus* (Neobisiidae, Pseudoscorpiones), from Yugoslavia. *Ibid*., **19**: 215-224.

——, —— & G. LEGG., 1995. Malformations in pseudoscorpions: a review. *Arch. Biol. Sci., Belgrade*, **47**: 77-100.

——, M. D. KRUNIĆ & M. M. BRAJKOVIĆ, 1981. Further records of teratological changes in the Neobisiidae (Neobisiidae, Pseudoscorpiones, Arachnida). *Bull. Br. arachnol. Soc*., **5**: 280-284.

——, ——, & —— 1983. Tergal and sternal anomalies in *Neobisium* CHAMBERLIN (Neobisiidae, Pseudoscorpiones, Arachnida). *J. Arachnol*., **11**: 243-250.

——, S. E. MAKAROV & J. S. RADOVANOVIĆ, 1996. Polymorphism in pseudoscorpions: changes of trichobothrial pattern in *Roncus pannonius* ČURČIĆ, DIMITRIJEVIĆ, & KARAMATA (Neobisiidae, Pseudoscorpiones). *Rev. suisse Zool*. H.S., **1**: 107-115.

DASHDAMIROV, S., & W. SCHAWALLER, 1995. Pseudoscorpiones from Middle Asia, Part 4 (Arachnida: Pseudoscorpiones). *Stuttgarter Beitr. Naturk*., **522A**: 1-24.

DIMITRIJEVIĆ, R. N., 1990a. Neka obeležja postembrionalnog razvića i teratoloških promena kod pseudoskorpija iz porodica Chthoniidae i Neobisiidae (Pseudoscorpiones, Arachnida). 241 pp. Ph. D. Thesis, University of Belgrade, Belgrade.

—— 1990b. Segmental and other malformations in *Neobisium simoni* (L. KOCH) and *N. bernardi* VACHON (Neobisiidae, Pseudoscorpiones). *C. R. XII Coll. europ. Arachnol., Paris (1990)*, **1**: 118-124.

—— 1992. The first record of sternal anomalies in *Chthonius* aff. *tetrachelatus* (PREYSSLER) (Chthoniidae, Pseudoscorpiones). *Arch. Biol. Sci., Belgrade*, **42**: 23P-24P.

DROGLA, R., 1988. Pseudoskorpione aus dem Naturschutzgebiet "Ostufer der Muritz" - Aberrationen und eine fur die DDR neue Art (Arachnida, Pseudoscorpiones). *Zool. Rundb. Bez. Neubrandenburg*, **5**: 10-15.

GILBERT, O., 1952. Three examples of abnormal segmentation of abdomen in *Dactylochelifer latreillei* (LEACH). *Ann. Mag. nat. Hist.*, **12**: 47-49.

HADŽI, J., 1930. Prirodoslovna istraživanja sjeverno-dalmatinskog otočja. I. Dugi i Kornati. *Prirod. istr. Kralj. Jugosl.*, **16**: 65-79.

IVANOVIĆ, J., 1987. Anomalije abdomena kod vrste *Neobisium carpaticum* BEIER (Neobisiidae, Pseudoscorpiones) iz Botaničke Bašte u Beogradu. 18 pp. B. Sc. Thesis, University of Belgrade, Belgrade.

JUDSON, M. L. I., 1985. Redescription of *Myrmochernes* TULLGREN (Chelonethida: Chernetidae). *Bull. Br. arachnol. Soc.*, **6**: 321-327.

—— 1990. Redescription of the bee-associate *Ellingsenius fulleri* (HEWITT & GODFREY) (Arachnida, Chelonethi, Cheliferidae) with new records from Africa, Europe, and Middle East. *J. nat. Hist.*, **24**: 1303-1310.

KÄSTNER, A., 1927. Pseudoscorpiones. After- oder Moosskorpione. *In*: P. SCHULTZE (ed.), *Biologie der Tiere Deutschlands, Berlin*, **18**, pp. 1-68.

LUČIĆ, L. R., 1995. Strukturne promene u segmentaciji abdomena tokom postembriogeneze *Neobisium carpaticum* BEIER, 1934, i *Roncus pannonius* ĆURČIĆ, DIMITRIJEVIĆ and KARAMATA, 1992 (Neobisiidae, Pseudoscorpiones, Arachnida). 97 pp. M. Sc. Thesis, University of Belgrade, Belgrade.

MAHNERT, V., 1991. Pseudoscorpions (Arachnida) from the Arabian Peninsula. In: *Fauna of Saudi Arabia*, **12**: 171-199.

PEDDER, I. J., 1965. Abnormal segmentation of the abdomen in six species of British pseudoscorpions. *Entomol.*, **98**: 108-112.

SATO, H., 1992. Abnormal segmentation of the abdomen in Japanese pseudoscorpions, *Allochthonius opticus* and *Garypus japonicus. Atypus*, **100**: 27-31. (In Japanese.)

WEYGOLDT, P., 1969. The Biology of Pseudoscorpions. 145 pp. Harvard University Press, Cambridge, Mass.

WITH, C. J., 1905. On Chelonethi chiefly from Australian region in the collection of the British Museum, with observations on the "coxal sac" and some cases of abnormal segmentation. *Ann. Mag. nat. Hist.*, **7**: 94-143.

ZLATKOVIĆ, M. R., 1989. Segmentalne anomalije kod pseudoskorpija *Roncus* i *Neobisium* (Pseudoscorpiones) iz okoline Žitoradje. 42 pp. B. Sc. Thesis, University of Belgrade, Belgrade, 42 pp.